

**H0004353-US**

## **Coupling a Tapered Optical Element to an Optical Fiber**

### **BACKGROUND OF THE INVENTION**

#### **Technical Field**

**[0001]** This invention relates to the field of fiber optic illumination and more specifically to a coupler suitable for attaching a tapered optical element to an optical fiber.

#### **Background Art**

**[0002]** While there are methods known for coupling fiber optic cables to one another, such methods have proven to be unsuitable for coupling a tapered optical element, such as a morphing concentrator, to an optical fiber. There is therefore a need to be able to cost effectively couple an optical fiber to a tapered non-imaging optical element especially for non-imaging optics applications.

### **SUMMARY OF THE INVENTION**

**[0003]** The present invention describes an apparatus and method of using a coupler to couple a tapered optical element to an optical fiber. In a preferred embodiment, the inventive coupler comprises a hollow silicone insert in a metal tube that is used to align an optical fiber and a tapered non-imaging optical element. A crimp tool deforms the metal tube and the coupler enough to fix the fiber and non-imaging optic in alignment. The silicone insert enables direct contact with the non-imaging optic without loss of total internal reflection. In accordance with my invention, the silicone insert includes "grabber features" to clamp around the parts. Advantageously, an index-matching medium is in contact with the opposing faces of the parts, reducing the fresnel reflection loss from 8% to less than 1%.

**H0004353-US**

**[0004]** According to a first aspect, the present invention provides a fiber optic coupler for a tapered optical element comprising:

a metal tube having an inner circumferential surface, a first open circular end and a second open circular end;

a clear hollow insert having a refractive index less than the tapered optical element is positioned within and abutting the inner circumferential surface of the metal tube;

the hollow insert being comprised of:

an input tapered region extending from the first open circular end for a first predetermined distance along a central axis, the tapered region including a first plurality of grabbers wherein each one of the first plurality of grabbers extends radially from the inner circumferential surface of the metal tube and the first plurality of grabbers collectively define a first portion of a cone extending from the first open circular end,

a coupling region, starting at the first predetermined distance from the first open circular end and extending a second predetermined distance along the central axis, the radial thickness of the coupling region defining a second portion of the cone extending from the first open circular end, and

a constant area region starting at the second predetermined distance from the first open circular end and extending to the second open circular end along the central axis, the constant area region including a second plurality of grabbers wherein each one of the second plurality of grabbers extends radially from the inner circumferential surface for a third predetermined distance.

**[0005]** According to a second aspect, the present invention provides a method for coupling a tapered optic element to an optical fiber comprising the steps of:

positioning a clear silicone insert upon an inner circumferential surface of a metal tube having a first open circular end and a second open circular end;

**H0004353-US**

forming an input tapered region from said clear silicone insert, said tapered region including a first plurality of grabbers extending radially from the inner circumferential surface of said metal tube;

forming a coupling region, from said clear silicone insert, said coupling region starting at a first predetermined distance from said first open circular end and extending a second predetermined distance along a central axis of said metal tube;

forming a constant area region, from said clear silicone insert, said constant area region including a second plurality of grabbers extending radially from the inner circumferential surface of said metal tube;

inserting said tapered optical element into said first open circular end of said metal tube and in contact with said first plurality of grabbers;

inserting said optical fiber into said second open circular end of said metal tube and in contact with said second plurality of grabbers; and

crimping said metal tube in order to mechanically secure the tapered optical element and the optical fiber.

**[0006]** The novel features of the present invention will become apparent to those of skill in the art upon examination of the following detailed description of the invention or can be learned by practice of the present invention. It should be understood, however, that the detailed description of the invention and the specific examples presented, while indicating certain embodiments of the present invention, are provided for illustration purposes only because various changes and modifications within the scope and spirit of the invention will become apparent to those of skill in the art from the detailed description of the invention and claims that follow.

### **Brief Description of the Several Views of the Drawing**

**H0004353-US**

**[0007]** FIG. 1 illustrates a fiber optic coupler in accordance with one specific illustrative embodiment of the present invention.

**[0008]** FIG. 2 depicts the internal structure of the fiber optic coupler of FIG. 1, before its use in accordance with my invention.

**[0009]** FIG. 3 shows a tapered optical element being optically connected to an optical fiber using a first embodiment of the fiber optic coupler of my invention, prior to crimping.

**[0010]** FIG. 4 shows the fiber optic coupler of FIG. 3, after crimping.

**[0011]** FIG. 5 shows a tapered optical element being optically connected to an optical fiber using a second embodiment of the fiber optic coupler of my invention, prior to crimping.

**[0012]** FIG. 6 shows the fiber optic coupler of FIG. 5, after crimping.

## DETAILED DESCRIPTION OF THE INVENTION

### Mode(s) for Carrying Out the Invention

**[0013]** Referring first to FIG. 1, a fiber optic coupler in accordance with one embodiment of my invention comprises a clear hollow insert **10**, composed of a material such as silicone, within a deformable tube **20**. The material used for the clear hollow insert advantageously has a lower refractive index than the tapered optical element or a coating of a lower refractive index is provided between the hollow insert **10** and the tapered optical element to prevent light leakage. In one particular embodiment, tube **20** is of metal and has an outer diameter of 5.7 millimeters and an inner diameter of 5.2 millimeters.

**H0004353-US**

**[0014]** FIG. 2 shows the internal structure of the fiber optic coupler of FIG. 1, before its use as a coupling element. The clear hollow insert **10** is composed of an input tapered region **15**, a coupling region **16**, and a constant area region **17** and advantageously is a molded part positioned against the inner surface of the metal tube **20**. The input tapered region **15** is defined by a first set of grabbers **11**, which are progressively closer together. Each one of the first set of grabbers **11** extends radially from the inner circumferential surface of the metal tube **20** and collectively defines a first portion of a cone. Advantageously, the taper of this cone matches the taper of the tapered optical element.

**[0015]** The output constant area region **17** is defined by a second set of grabbers **12**, which are equi-spaced from each other. Each one of the second set of grabbers **12** extends radially from the inner circumferential surface for a predetermined distance. Advantageously, this predetermined distance matches the diameter of the optical fiber.

**[0016]** Advantageously, these grabber regions provide crimp zones, as described below, which allow the use of a standard crimp tool such as the CrimpAll series produced by Paladin.

**[0017]** Referring now to FIG. 3, there is depicted a fiber optic coupler, prior to a crimping operation, comprising the metal tube **20** and clear hollow insert **10**. As described above, the clear hollow insert is made up of the tapered region **15** including the first set of grabbers **11**, the coupling region, and the constant area region **17** including the second set of grabbers **12**. A tapered optical element **40** is positioned next to a fiber optic cable **50** within my inventive coupler. The tapered optical element **40** is inserted into the input tapered region **15** and the fiber optic cable **50** is inserted into the constant area region **17** through the opposite end of the coupler. Both the tapered optical element **40** and the fiber cable **50** protrude into the coupling region **16**, where the material of the clear hollow insert has enough flex to accommodate a portion of the tapered optical element **40**. An index-matching

**H0004353-US**

medium **60** is positioned between the mating faces of the tapered optical element **40** and the optical fiber **50**.

**[0018]** In one preferred embodiment, the index-matching medium is microencapsulated silicone **60** that is injected into the center of the coupler during manufacturing, and does not cure or dry-out prior to use. Upon contact from faces of the opposing optics, the encapsulant ruptures, and the index-coupling medium makes contact with the optics. In this preferred embodiment, the index matching medium **60** is inserted at the optical interface between a face of the tapered optical element **40** and a corresponding face of the optical fiber **50**.

**[0019]** In another embodiment, the index-matching medium is a thin membrane of silicone that is part of the clear hollow insert **10**. Upon crimping, sufficient energy is imparted to the membrane to allow it to flow sufficient to provide the coupling medium.

**[0020]** Refer now to FIG. 4, which depicts my inventive coupler after the crimping operation. After the tapered optical element **40** and the fiber optic cable **50** are inserted into the coupler, they are mechanically secured by crimping the metal tube **20** and the coupler **10** at a first crimp zone **31** and a second crimp zone **32**.

**[0021]** FIG. 5 shows a second embodiment of my invention in which microencapsulated silicone **61** is embedded in, or injected into, the coupling region **16** of the clear hollow insert. During the crimping process, certain of the microcapsules are broken and release index-matching silicone **60** as shown in FIG. 6. This index-matching silicone **60** optically connects the opposing faces of the tapered optical element **40** and the optical fiber **50**.

**[0022]** A tapered optical element is coupled to an optical fiber using my inventive coupler using the following steps. First, a tapered optical element **40** is inserted into the first open circular end of the coupler and in contact with the first set of

**H0004353-US**

grabbers **11**. Next, an optical fiber **50** is inserted the second open circular end of the coupler and in contact with the second set of grabbers **12**. Finally, the metal tube **20**, comprising the outside of the coupler, is crimped to mechanically secure the tapered optical element **40** and the optical fiber **50**.

**Alternate Embodiments**

**[0023]** Alternate embodiments may be devised without departing from the spirit or the scope of the invention.

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